AD

AD-E400 840

TECHNICAL REPORT ARLCD-TR-82007

REACTIVITY OF EXPLOSIVES/SEDIMENT MIXTURES

MAURICE S. KIRSHENBAUM

MAY 1982

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
LARGE CALIBER
WEAPON SYSTEMS LABORATORY
DOVER, NEW JERSEY

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report ARLCD-TR-82007	2. GOVT ACCESSION NO. AD-A118 012	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) REACTIVITY OF EXPLOSIVES/SEDIMENT MIXTURES		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Maurice S. Kirshenbaum		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS ARRADCOM, LCWSL Energetic Materials Division (DRDAR-LCE) Dover, NJ 07801		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS ARRADCOM, TSD STINFO Div (DRDAR-TSS) Dover, NJ 07801		12. REPORT DATE May 1982
		13. NUMBER OF PAGES 30
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) U.S. Army Toxic & Hazardous Materials Agency DRXTH-TE-D Aberdeen Proving Ground, MD 21010		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Impact sensitivity	TNT
Friction sensitivity	RDX
Electrostatic sensitivity	
Thermal sensitivity	
Shock sensitivity	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The hazards associated with the excavation, transportation, and incineration of dry humus sediments contaminated with TNT and/or RDX were assessed. Impact, friction, electrostatic, shock, and thermal sensitivity tests revealed that the shock hazard was the controlling factor in determining the safe explosive concentrations. The test method used indicates that there is probably no explosive hazard if the total concentrations of the energetic materials are not greater than 25% by weight and the sediments in the incinerator are unconfined.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

CONTENTS

TABLES

FIGURES

INTRODUCTION

In the past, the standard practice at Army Ammunition Plants was to dispose of explosive contaminated wastewater by transferring the water to lagoons. This practice resulted in explosives being concentrated in the bottom sediments where they represent an environmental hazard to surface and ground water. The explosive content in the sediments varies from lows of parts per million to highs up to 50% cyclotrimethylenetrinitramine (RDX) and trinitrotoluene (TNT) in the worst case. In compliance with Federal Environmental Regulations, the U.S. Government has begun plans to clean up several of these wastewater lagoons at various Army Ammunitions Plants throughout the country. Since the Resource Conservation and Recovery Act (RCRA) prohibits placing reactive wastes in impoundments or landfills, tests are being conducted on the sediments to determine whether or not they are nonexplosive and/or nonreactive.

A possible method to treat the sediments is to excavate the sediments and then incinerate them, but unfortunately, information needed to assess the hazards associated with the excavation, transportation, and incineration of such sediments is not available. Thus the Energetic Materials Division (EMD), Large Caliber Weapon Systems Laboratory (LCWSL), U.S. Army Armament Research and Development Command (ARRADCOM), Dover, NJ, was requested to conduct such a study by the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) to obtain this information. The following describes the results of this study.

OBJECTIVE

The program was divided into two phases. The objective of the initial phase was to determine the maximum concentration of four explosives, TNT, RDX, 60/40 TNT/RDX, and 40/60 TNT/RDX, that lagoon sediments could contain and still not constitute a safety hazard. In the second phase of the program, the sensitivity of contaminated lagoon sediments from four different Army Ammunition Plants was determined.

TECHNICAL APPROACH

Phase I was conducted by preparing explosive sediment mixtures with different explosive concentrations and testing these compositions to determine their relative sensitivities to impact, shock, friction, heat, and spark. Wet impact and wet shock sensitivity tests were also conducted to determine the minimum amount of water that any mixtures failing the dry shock sensitivity test had to contain to make them insensitive to these stimuli. The impact sensitivity test was first conducted with RDX, mixed with two different sediments, humus and clay, provided by USATHAMA. The sediment type that was determined to be the most impact sensitive with RDX was then used in the remaining tests. Therefore, only one sediment type was used in the remainder of Phase I testing.

In the second phase of the program, 20 wet, contaminated lagoon sediment samples were supplied by USATHAMA from four different Army installations: Alabama Army Ammunition Plant (AAAP), Umatilla Army Depot (UAD), Louisiana Army Ammunition Plant (LAAP), and Savanna Army Depot (SAD). The samples were first analyzed by Atlantic Research Corporation to determine their relative moisture and explosive content (ref 1), and then tested at ARRADCOM to determine their relative sensitivity to impact, shock, and friction.

EXPERIMENTAL

Sample Preparation

Uncontaminated humus sediment was shipped from SAD and uncontaminated clay sediment came from the LAAP. Both sediments were dried in a vacuum oven at 60°C for 24 hours before testing. In addition, the clay sediment was sieved through a 25-mesh screen. The dry and wet explosive-sediment mixtures were prepared on a weight percent basis.

In the second phase of the program, the 20 wet contaminated lagoon sediment samples were tested as received. The explosive content and the percent moisture data for the sediment samples presented in reference 1 are summarized in table 1. The TNT and RDX explosive levels varied from less then 0.01% to greater than 18% and 3% by weight, respectively. The moisture content varied from 7% to greater than 50% by weight.

Sensitivity Tests

Impact

The impact sensitivity tests were performed with the Explosives Research Laboratory (ERL), sometimes called the Naval Ordnance Laboratory (NOL) Type 12 impact tester. The apparatus uses a 2.5-kg steel drop weight with a 30 mg sample resting on sandpaper between two steel anvils. The drop weight is raised pneumatically to the desired height. A detailed description of the apparatus is contained in reference 2.

The drop height corresponding to the 50% probability of initiation was used as a measure of impact sensitivity of the sediment-explosive mixtures. The 50% initiation point was determined by means of the Bruceton Up-and-Down Method (ref 3). The maximum explosive concentration levels, which would not pose an explosive hazard from impact, were also determined. Insensitivity to impact was arbitrarily considered as no explosive reaction in 20 trials using a 2.5-kg weight at 240 cm.

The amount of the test sample consumed during a run varied from a low level, evidenced by a very slight sound or a slight burn mark to compl te burning or detonation. The criterion for ini' ation in this study was any evidence of burning or detonation observed during impact or in the post-test examination of the sample.

Impact sensitivity tests with wet samples were conducted to determine the minimum amount of water that the 40/60 explosive-humus sediment mixtures have to contain to make them insensitive to impact. The explosive-sediment mixture used for each explosive was the one which contained the lowest concentration of explosive of those that detonated in the shock sensitivity test. The minimum amount of water for desensitization was defined as the water concentration which resulted in no initiation in 20 trials using a 2.5-kg weight at 240 cm. Note that the criterion for initiation in the impact test with wet samples was any audible sound, whereas the criterion for the impact test with dry samples was any evidence of decomposition, such as a slight burn mark. If the dry impact criterion were used, the results would have shown that all of the mixtures containing 40% explosive were sensitive to impact, even when excess water was used. (The humus sediment supplied from SAD became saturated with water when the concentration was 30% by weight.) The wet criterion is not inconsistent with the dry crierion because although explosives may be initiated under water, they will not always propagate.

Friction

The ARRADCOM (formerly called Picatinny Arsenal) large-scale friction pendulum apparatus used in this test consisted of a fixed steel anvil and a weighted pendulum with a steel shoe. A 7 gram sample is placed on the anvil and subjected to a series of glancing blows by the shoe, which is automatically released from a height of 1 meter. The pass criterion for this test was that there would be no indication of explosion, burning, or local cracking in ten consecutive trials. A detailed description of the apparatus is given in reference 2.

Each explosive-sediment mixture, which was determined to be nonpropagating by the large scale gap test (shock sensitivity test), was tested for friction sensitivity.

Electrostatic

An approaching electrode apparatus was used to determine whether the explosive sediment samples passed the electrostatic sensitivity requirement. The pass criterion for this test was that there would be no reactions in 20 consecutive trials at the 0.25 joule energy level (0.02 microfarad capacitor charged to 5000 VDC). Each explosive-sediment mixture, which was determined to be nonpropagating by the large scale gap test (shock sensitivity test), was tested for electrostatic sensitivity.

Differential Thermal Analysis/Thermogravimetric Analysis

Simultaneous recordings of differential thermal analysis (DTA) and thermogravimetric analysis (TGA) (weight change measurement) were obtained as a function of furnace temperature with a Mettler TA-2 thermoanalyzer at a heating rate of 10°C/min in static air from room temperature through decomposition.

Shock

The large scale gap test (ref 2) without a gap was used to assess the shock sensitivity of the explosive-sediment mixtures. In this test, the maximum explosive concentration level, which would not pose an explosive hazard from shock, was determined by varying the explosive content in the mixture. About 300 grams of the test material was loaded into steel pipes, 4.76 cm (1.875 in.) o.d., 3.6 cm (1.44 in.) i.d., by 14 cm (5.5 in.) long. A donor explosive, consisting of two pentolite pellets each 5.08 cm (2 in.) in diameter by 2.54 cm (1 in.) long, were placed on top of the pipe and initiated with an electric detonator. No gap (barrier) was used between the donor explosive and the test mixture. The donor provided an explosive shock pressure to the test mixture. The criterion for a detonation in this test was any deformation in the 0.95 cm (3/8 in.) thick steel witness plate, which was placed at the end of the steel pipe away from the point of initiation. A picture of the set up is shown in figure 1.

Flame

Two different fast cook-off tests were used to determine the relative sensitivity of the explosive-sediment mixtures to flame, unconfined and confined. In both tests, the cook-off apparatus consisted of a fire pan containing 300 mL No. 1 fuel oil and steel cook-off bomb containing the dry explosive-sediment mixture being tested. The pipe bomb was suspended in the center of the fire plan, 6.4 cm (2 1/2 in.) above the top of the fuel oil. The pipe bomb was suspended vertically in the unconfined test and horizontally in the confined test. The fuel was ignited by means of an electric match and the effect of the cook-off was recorded.

In the unconfined test, two different size steel pipe bombs were used: 2.54 cm (1 in.) diameter by 5 cm (2 in.) long, and 3.2 cm (1 1/4 in.) diameter and 15 cm (6 in.) long. Both pipes were capped with a pipe cap only at one end. Two tests were conducted with each size pipe.

In the confined test, the steel bomb consisted of a standard 3.8 cm (1 1/2 in.) long, 2.54 cm (1 in.) diameter pipe nipple enclosed with two pipe caps. The test was conducted twice. The relative severity of the reaction was compared to the following five distinct levels of severity:

Level 1: Mild burning - very little, if any, damage is done.

Level 2: Mild pressure rupture - the end cap is usually ruptured very mildly.

Level 3: Violent pressure rupture - some large fragments from the bomb are produced.

Level 4: Low order detonation - a greater number of fragments are formed and of a much smaller size.

Level 5: High order detonation - a still greater number and smaller fragments are formed.

RESULTS AND DISCUSSION

Impact sensitivity of dry RDX-humus sediment mixtures and dry RDX-clay sediment mixtures as a function of RDX concentration are shown in table 2*. The data shows that RDX-humus sediment mixtures are more sensitive to impact than RDX-clay sediment mixtures. For example, the drop height corresponding to the 50% probability of initiation for a 10% RDX-90% sediment mixture was 56 cm for the humus sediment and 103 cm for the clay sediment. It should also be noted that with both types of sediments, the addition of sediment to the explosive resulted in a mixture much more sensitive to impact than RDX alone. A 20/80 RDX/humus mixture exhibited a 50% initiation height of 11 cm, whereas a 100% RDX sample had a 40 cm drop height. A 30/70 RDX/clay mixture had a 17 cm 50% initiation height. Since the humus sediment gave more sensitive mixtures with RDX, the remaining tests were carried out using only the humus sediment.

The TNT-humus sediment (dry) results are listed in table 3. The addition of humus to TNT also made TNT much more sensitive to impact. A 100% TNT sample had a 50% initiation height of 240 cm, whereas a 20/80 TNT/humus sediment mixture had a 34 cm initiation height. A 5/95 TNT/humus mixture had a 240 cm initiation height. The table shows two different initiation heights for the same explosive concentration. The initiation criterion for the lower height was any evidence of decomposition. The higher height criterion was any audible sound.

Tables 4 and 5 show the dry 60/40 TNT/RDX-humus sediment mixture and the dry 40/60 TNT/RDX-humus sediment mixture results, respectively. Similar results were obtained as those for RDX-humus and TNT-humus mixtures. A 10/90 explosive/humus

*The criteria (burn/sound) used in this study were much more severe than those used by other organizations, which use an audible sound detected by means of a microphone. Thus, in the discussion, a reaction is not always an explosion. The burn criterion was not considered too strict because the impact test was used as a screening test, whereas the shock sensitivity test was the controlling factor in determining the safe explosive concentration.

mixture was much more impact sensitive than the explosives without the humus sediment. No impact initiation was obtained in 20 trials at a height of 240 cm for a mixture containing 2 1/2% explosive.

The impact sensitivity test results for the wet explosive-humus sediment mixtures containing 40% explosives are given in table 6. The data shows that the 40/60 explosive/humus sediment mixtures have to contain 10 to 25% by weight water to be insensitive to impact.

The shock sensitivity test results (table 7) indicate that dry humus sediment containing 30% or less by weight RDX and/or TNT will not support a propagating detonation in the diameter and length of pipe tested, whereas 40% or more explosive will. Similar results were obtained when the explosive-humus sediment mixture (60/40 TNT/RDX) contained 20% by weight water, the maximum amount of water tested. The effect of higher moisture contents is unknown at this time.

The ARRADCOM large-scale friction pendulum test with the steel shoe and the approaching electrode electrostatic sensitivity test were conducted on the explosive-sediment mixtures (30/70 explosive/humus sediment) considered shock insensitive. None exhibited friction or electrostatic sensitivity.

The experimental DTA and TGA results are summarized in tables 8 and 9, respectively. A typical DTA/TGA thermogram is shown in figure 2. The analytical data shows that the addition of TNT, RDX, and TNT/RDX mixtures to humus sediment did not significantly increase the thermal sensitivity of the explosives. As can be seen from table 9, RDX, the most sensitive explosive present in the lagoon sediments, has a maximum rate of weight change of 11 mg/min. The rate decreased to 8.75 mg/min with the addition of 20% humus sediment, then to 3.3 mg/min when the mixture contained 20% by weight RDX, and finally the rate was too slow to be detected when only 2.5% by weight RDX was present.

The flame sensitivity (fast cook-off) test results are summarized in table 10. Only one explosive-sediment mixture was tested: 30% by weight of a 60/40 TNT/RDX explosive mixture and 70% humus sediment. This mixture burned and did not detonate. In the unconfined tests, the mixtures burned steadily for about 1 1/2 minutes until all the explosives were consumed. After the test, examination showed that the pipe contained a well-charred mixture. In the confined test, there was a mild rupture to the end cap after about 2 1/2 minutes. The only damage to the pipe bombs was where the back of one end cap blew out.

In the second phase of the program, all 20 wet, contaminated lagoon sediment samples were tested for impact sensitivity. No impact initiation was obtained in 20 trials at a height of 240 cm. The DTA/TGA and shock sensitivity tests were carried out on ten samples which contained the highest explosive concentration: sample numbers SAD-1 through 5, LAAP-1 and 2, UAAP-1 and 5, and AAAP-1. No propagations occurred in the shock test. The DTA and TGA data are listed in tables 11 and 12, respectively. A typical DTA/TGA thermogram is shown in figure 3. The five samples with the highest explosive content were subjected to the large-scale friction pendulum test. None exhibited friction sensitivity. The highest explosive concentration tested was 18% TNT and 4% RDX in sample number SAD-4. This sediment had a 50% moisture content. It should be noted that in

Phase I of this program, a 30% moisture content was the highest concentration that could be attained with the humus sediment from SAD before the sediment became concentrated.

CONCLUSIONS

The impact method and criteria used in this study show that dry humus sediment contaminated with RDX is more sensitive than dry clay sediment contaminated with the explosive.

The maximum explosive concentration by weight that can be present in dry humus from SAD, without being impact reactive, is approximately 2 1/2% of a 60/40 or a 40/60 TNT/RDX mixture. Mixtures containing 40% by weight TNT and/or RDX should contain 10 to 25% by weight water to be insensitive to impact.

The DTA/TGA data shows that sediment mixtures containing at least 10% by weight TNT and/or RDX are thermally reactive, which indicates that such mixtures unconfined could burn when heated to 175 to 200°C. The TGA data indicates that the thermal hazard is eliminated upon reduction of the concentration of TNT and/or RDX to 5%, since with such samples, the rate of weight loss was too slow to be detected.

Although humus sediments from SAD containing 30% by weight TNT and/or RDX are more sensitive to impact than the explosives alone, a detonation did not propagate through a mixture containing 30% or less TNT and/or RDX in the confined configuration tested. In a fuel fire, sediment containing 30% by weight of a 60/40 TNT/RDX mixture burned when unconfined and resulted in a mild pressure reaction when confined in a 1-inch diameter steel pipe. Based on our judgment and the number of tests conducted, it is felt that with proper precautions, dry humus sediments (similar to the sediment from SAD) containing up to 25% by weight explosive can be excavated, transported, and incinerated safely. For additional safety, the sediments could contain 15 to 25% by weight moisture. Since dry humus sediments containing more than 2 to 3% by weight of a 60/40 or a 40/60 TNT/RDX mixture are impact reactive, proper precautions should be taken during excavation to prevent personnel from injury. Dry humus sediment mixtures containing more than 25% by weight explosive, are probably shock sensitive, and should not be excavated by any means which can transmit a shock to the sediment. Sediments treated in an incinerator should be unconfined to prevent pressure build up and rupture.

REFERENCES

1. R.S. Wentsel, A.R. Ennis, and J.F. Kitchens, "Engineering and Development Support of General Decon Technology for the DARCOM Installation Restoration Program, Task 9. Lagoon Sediment Analysis," Contractor Report DAAK11-80-C-0027, Atlantic Research Corporation, August 1981.

2. TTCP Panel O-2 (Explosives) Working Group on Sensitivity, "Manual of Sensitivity Tests," Canadian Armament Research and Development Group on Sensitiveness, February 1966.

3. W.J. Dixon and A.M. Mood, "A Method for Obtaining and Analyzing Sensitivity Data," J. Amer. Statis. Assn., 143, 1948, p 109.

Table 1. Explosive levels and moisture content for lagoon sediment samples

Sample no.	TNT concentration (%)	RDX concentration (%)	Moisture content (%)
AAAP[a]-1	<0.01	<0.01	23
-2	<0.01	<0.01	37
-3	<0.01	<0.01	21
-4	<0.01	<0.01	27
-6	<0.01	<0.01	37
UAD[b] -1	1.05	<0.05	14
-2	0.01	<0.05	7
-3	<0.01	<0.05	14
-4	0.01	<0.05	14
-5	0.34	<0.05	15
LAAP[c]-1	3.00	1.80	25
-2	0.78	0.69	28
-3	0.02	0.04	29
-4	0.37	0.30	54
-5	<0.01	<0.01	30
SAD[d] -1	1.20	<0.05	26
-2	15.20	0.31	33
-3	14.40	0.30	46
-4	18.10	0.42	51
-5	14.90	0.35	56

[a]AAAP - Alabama Army Ammunition Plant
[b]UAD - Umatilla Army Depot
[c]LAAP - Louisiana Army Ammunition Plant
[d]SAD - Savanna Army Depot

Table 2. Impact sensitivity as a function of RDX-sediment concentration

(ERL-Type 12 Tool, 2 1/2-kg drop weight)

RDX concentration (% by weight)	Height (cm)	Fired (%)
RDX-humus sediment (dry)		
100	40	50
80	<10	50
40	<10	50
20	11	50
10	56	50
5	85	50
2 1/2	111	50
1 1/46	215	50
RDX-clay sediment (dry)		
100	40	50
80	<10	50
40	16	50
30	17	50
20	46	50
10	103	50
2 1/2	240	21

Table 3. Impact sensitivity as a function of TNT-humus sediment concentration

(ERL-Type 12 Tool, 2 1/2-kg drop weight)

TNT concentration (% by wt)	Height (cm)	Fired (%)	Type reaction
100	240	55	Explosion
100	240	70	Burn
80	92	50	Explosion
80	23	50	Burn
40	78	50	Explosion
40	17	50	Burn
20	34	50	Burn
10	131	50	Burn
5	240	52	Burn

Table 4. Impact sensitivity as a function of 60/40 TNT/RDX-humus sediment concentration

(ERL-Type 12 tool, 2 1/2-kg drop weight)

Explosive concentration (% by wt)	Height (cm)	Fired (%)
100	84	50
40	<10	50
10	77	50
5	111	50
2 1/2	240	0

Table 5. **Impact sensitivity as a function of 40/60 TNT/RDX-humus sediment concentration**

(ERL-Type 12 tool, 2 1/2-kg drop weight)

Explosive concentration (% by wt)	Height (cm)	Fired (%)
100	78	50
50	<10	50
25	15	50
10	58	50
5	95	50
2 1/2	240	0

Table 6. Impact sensitivity results of wet samples of 40/60 explosive-humus sediment mixtures

(ERL-Type 12 tool, 2 1/2-kg drop weight at 240 cm)

Explosive composition (% by wt)	Water concentration (% by wt)	
	No initiation	Initiation
40 RDX	25	20
40 TNT	10	5
24 TNT/16 RDX	15	10
16 TNT/24 RDX	15	10

Table 7. Shock test results as a function of explosive-humus sediment concentration

Explosive	Concentration (% by wt)	Results
TNT	60	Propagation - hole in steel witness plate
	50	Propagation - hole in steel witness plate
	40	Propagation - steel witness plate split in two
	30	No propagation
RDX	40	Propagation - hole in steel witness plate
	30	No propagation
	20	No propagation
60/40 TNT/ RDX	40	Propagation - hole in steel witness plate
	30	No propagation
	25	No propagation
40/60 TNT/ RDX	40	Propagation - hole in steel witness plate
	30	No propagation
	25	No propagation
60/40 TNT/ RDX (20% by wt water)	50	Propagation - steel witness plate split into three pieces
	40	Propagation - steel witness plate split into two pieces
	30	No propagation

Table 8. DTA results for explosive-humus sediment mixtures

(Mettler TA-2 thermoanalyzer, 10°C/min in static air)

Explosive	Concentration % by wt	First endotherm (°C) onset	First endotherm (°C) peak	Second endotherm (°C) onset	Second endotherm (°C) peak	First exotherm (°C) onset	First exotherm (°C) peak	Second exotherm (°C) onset	Second exotherm (°C) peak
TNT	100	75	78[a]	222	246	246	280		
	80	76	80[a]	207	250	250	265		
	40	75	79[a]	195	239	239	277		
	20	76	80[a]	200	245	245	268		
	10	74	78[a]	-	-	-	-		
	5	74	78[a]	-	-	-	-		
RDX	100	184	200[b]			200	233		
	80	182	200[b]			200	236		
	40	184	200[b]			200	240		
	20	183	200[b]			200	237		
	10	196	198[b]			198	231		
	5	197	200[b]			200	220		
	2.5	-	-			201	208		
	1.25	-	-			194	201		
40/60 TNT/RDX	100	74	79[a]			188	230	270	356
	40	74	78[a]			185	230	260	342
	25	74	78[a]			174	228	265	343
	10	75	78[a]			188	232		
	5	188	199[b]			199	220		
	2.5	196	200[b]			200	213		

[a]Melting point of TNT
[b]Melting point of RDX

Table 9. TGA results for explosive-humus sediment mixtures

(Mettler TA-2 thermoanalyzer, 10°C/min in static air)

Explosive	Concentration (% by weight)	Weight Loss Start (°C)	End (°C)	(%)	$(dw/dt)_m$[a] (mg/min)	$(dw/dt)_t$[b] (°C)
TNT	100	115	310	100	3.0	223
	80	112	272	80	4.0	230
	40	149	300	41	2.3	245
	20	133	310	29	2.3	247
	10	155	300	5	c	c
	5	153	262	3.7	c	c
RDX	100	169	370	100	11.5	232
	80	174	390	81	8.75	235
	40	177	343	38	3.5	238
	20	172	287	18.5	3.3	236
	10	174	300	9.2	1.3	230
	5	168	230	4.0	0.5	220
	2.5	192	334	2.4	c	c
	1.25	194	468	1.5	c	c
40/60 TNT/RDX	100	138	426	99	3.5	229
	40	145	455	33	1.0	230
	25	141	375	24	3.15	228
	10	150	280	10.6	0.8	233
	5	195	420	3.8	c	c
	2.5	188	318	2.5	c	c

[a] $(dw/dt)_m$ is the maximum rate of weight loss

[b] $(dw/dt)_t$ is the temperature at the maximum weight loss rate

[c] Weight loss rate was too slow to be detected.

Table 10. Flame sensitivity results for 30/70 of a (60/40) TNT/RDX-humus sediment mixture

Steel bomb	Wt explosive (g)	Results
Unconfined, 2.54 cm (1 in.) diameter by 5.08 cm (2 in.) long	37	Burned for 80 seconds; bomb contained well charred mixture
"	37	After burning for 20 seconds, wire broke and bomb fell into fire pan
Unconfined, 3.2 cm (1 1/4 in.) diameter by 15.2 cm (6 in.) long	160	Burned for 98 seconds; bomb contained well charred mixture
"	150	Burned for 76 seconds; bomb contained well charred mixture
Confined, 2.54 cm (1 in.) diameter by 3.8 cm (1 1/2 in. long)	37	Mild pressure rupture after 166 seconds; back of one end cap blew out
"	37	Mild pressure rupture after 153 seconds; back of one end cap blew out

Table 11. DTA results for lagoon sediment samples

(Metler TA-2 thermoanalyzer, 10°C/min in static air)

Sample	Endotherm (°C) onset	Endotherm (°C) peak	Exotherm (°C) onset	Exotherm (°C) peak	Comment
Savanna no. 1	30	64	208	300	small exotherm
Savanna no. 2	31	80	225	363	moderate exotherm
Savanna no. 3	35	85	214	300	moderate exotherm
Savanna no. 4	28	83	138	310	very large exotherm
Savanna no. 5	53	100	200	306	very large exotherm
Louisiana no. 1	50	58	200	225	very small exotherm
Louisiana no. 2	40	64	238	320	very small exotherm
Alabama no. 1	27	81	200	298	very small exotherm
Umatilla no. 1	No definite endotherm or exotherm to 305°C				
Umatilla no. 5	No reactions to 305°C				

Table 12. TGA results for lagoon sediment samples

(Mettler TA-2 thermoanalyzer, 10°C/min in static air)

Sample	Water weight loss (%)	Water weight loss (temp range °C)	(%)	Decomposition (temp range, °C)	Residue (%)
Savanna no. 1	13	30-73	5	130-300	82
Savanna no. 2	22	31-100	29	100-300	49
Savanna no. 3	37	35-100	16	100-300	47
Savanna no. 4	47	28-118	22	118-420	31
Savanna no. 5	36	50-120	29	120-403	35
Louisiana no. 1	10	50-67	4	173-427	86
Louisiana no. 2	12	38-75	3	183-375	85
Alabama no. 1	21	27-100	3	100-340	77
Umatilla no. 1	0	-	11	140-405	99
Umatilla no. 5	6	40-66	11	66-305	93

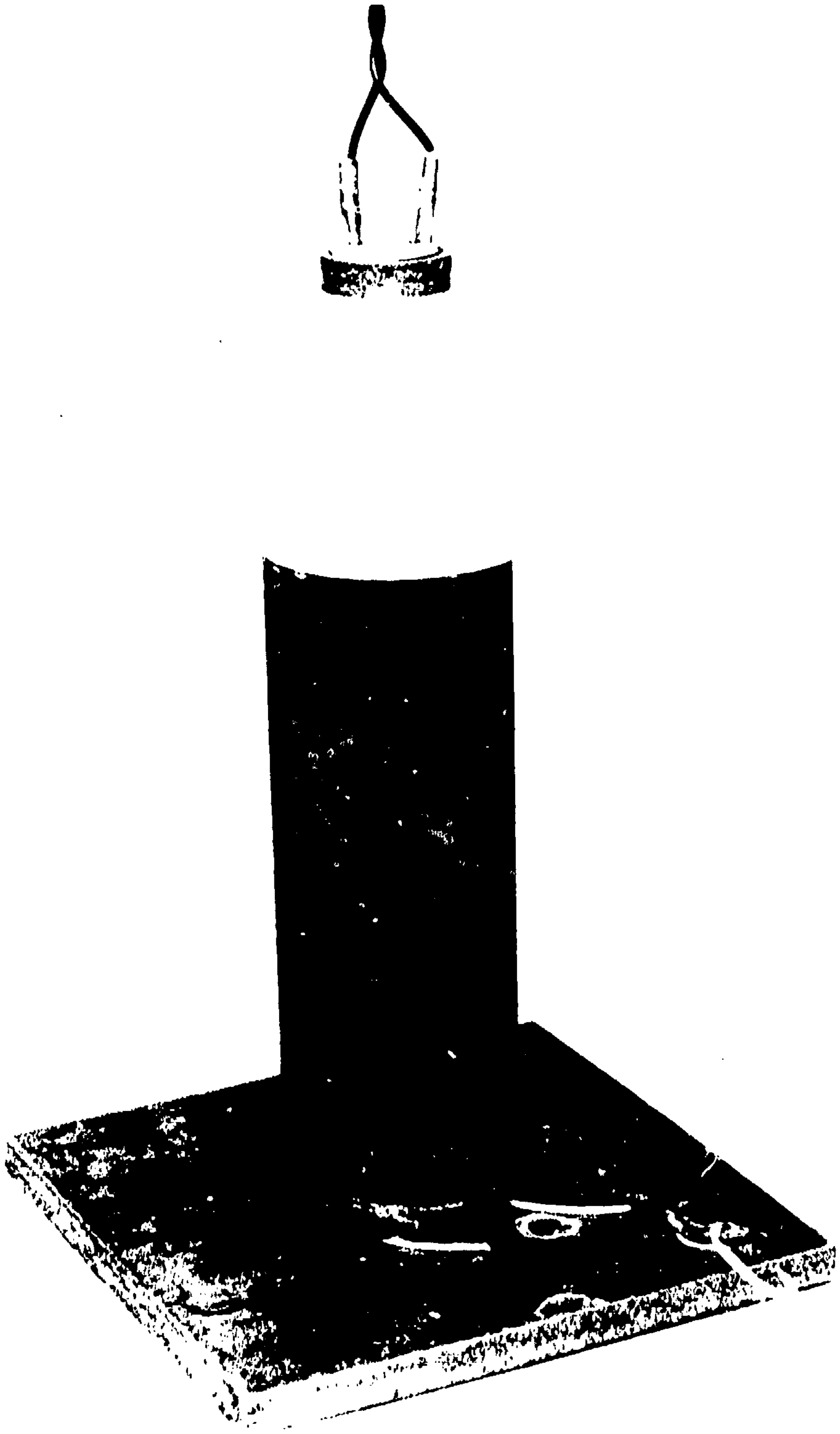

Figure 1. Large-scale gap test

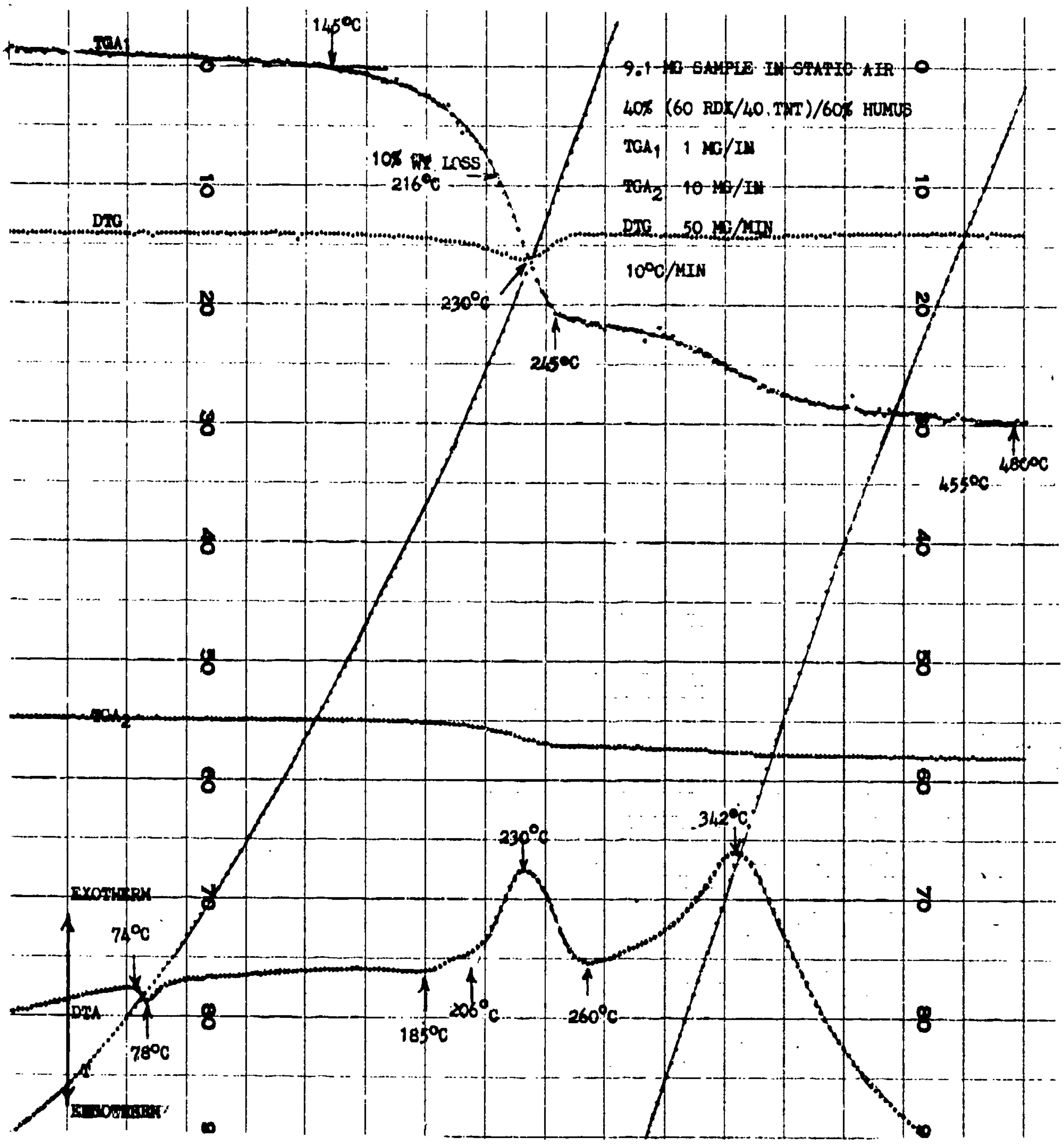

Figure 2 DTA/TGA thermogram of 40% (60 RDX/40 TNT)/60% humus (in air)

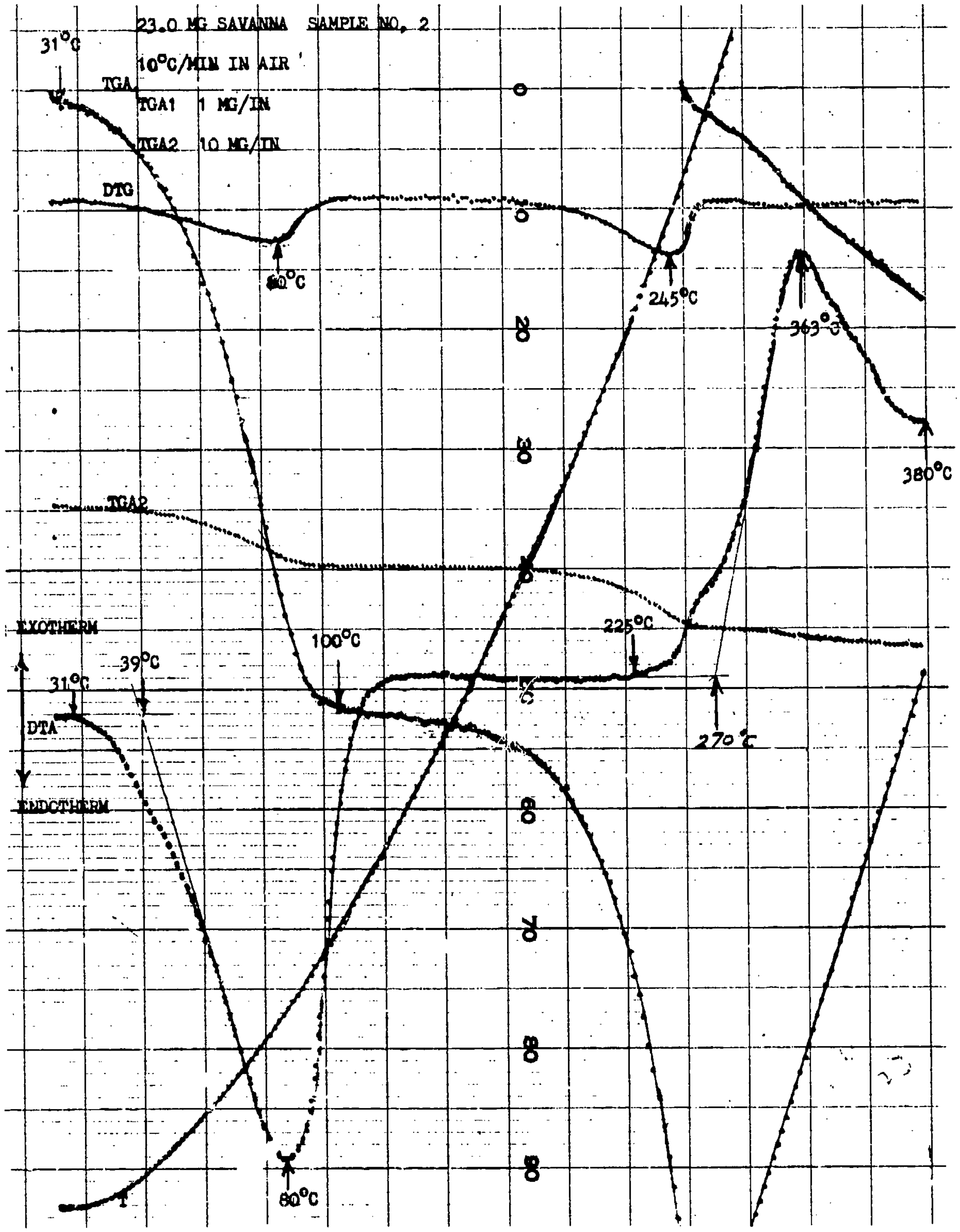

Figure 3. DTA/TGA thermogram of Savanna sample no. 2

DISTRIBUTION LIST

Commander
U.S. Army Toxic & Hazardous Materials
   Agency
ATTN: DRXTH-TE-D (2)
Aberdeen Proving Ground, MD 21010

Chief
Benet Weapons Laboratory, LCWSL
U.S. Army Armament Research and
   Development Command
ATTN: DRDAR-LCB-TL
Watervliet, NY 12189

Commander
U.S. Army Armament Materiel
   Readiness Command
ATTN: DRSAR-LEP-L
Rock Island, IL 61299

Director
U.S. Army TRADOC Systems
   Analysis Activity
ATTN: ATAA-SL
White Sands Missile Range, NM 88002

Administrator
Defense Technical Information Center
ATTN: Accessions Division (12)
Cameron Station
Alexandria, VA 22314

Commander/Director
Chemical Systems Laboratory
U.S. Army Armament Research and
   Development Command
ATTN: DRDAR-CLJ-L
   DRDAR-CLB-PA
APG, Edgewood Area, MD 21010

Director
Ballistic Research Laboratory
U.S. Army Armament Research and
   Development Command
ATTN: DRDAR-TSB-S
Aberdeen Proving Ground, MD 21005

Director
U.S. Army Materiel Systems
Analysis Activity
ATTN: DRXSY-MP
Aberdeen Proving Ground, MD 21005

Chief
Special Forces School
USIMA
ATTN: Staff Sgt Monahan
Ft. Bragg, NC 28307

Commander
U.S. Army Armament Research and
Development Command
ATTN: DRDAR-GCL
DRDAR-LCE, Dr. R.F. Walker (3)
DRDAR-LCE-D, Mr. M. Kirshenbaum (15)
Mr. W. Voreck
Mr. L. Avrami
DRDAR-SF
DRDAR-TSS (5)
Dover, NJ 07801

Commander
U.S. Naval Surface Weapons Center
White Oak Laboratory
ATTN: Technical Library
Silver Spring, MD 20910

Commander
U.S. Naval Weapon Center
ATTN: Technical Library
China Lake, CA 93555

Commander
U.S. Ordnance Station
ATTN: Technical Library
Indian Head, MD 20640

Commander
Air Force Armament Development and
Test Center
ATTN: AFB Technical Library
Eglin AFB, FL 32542

Lawrence Livermore Laboratory
ATTN: Technical Library
P.O. Box 808
Livermore, CA 94550

Los Alamos Scientific Laboratory
ATTN: Technical Library
Los Alamos, NM 87544